INTEGRATED TRAIL IMPACT, ASSESSMENT AND MONITORING TO MEET ECOSYSTEM RESEARCH AND MONITORING NEEDS.

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SUMMARY
Participation in backcountry recreation is growing and changing, increasing the dilemma of how to balance preservation and use values in Canadian protected areas. Recreation ecology research is beginning to evaluate ecological changes in wilderness, including impacts to vegetation, and soils. As a result of visitor use, Backcountry recreation planning models typically require defining acceptable conditions then monitoring and correcting undesired or unacceptable changes. This process involves using science-based information to support, implement and evaluate the success of values-based decisions. This paper focuses on the appropriateness and quality of the variety of methods used to assess, understand and attempt to predict soil and vegetation changes along trail corridors. It also critically examines past trail monitoring goals, typical indicators and measurement methods. It then presents an integrated method that uses a balance of qualitative and quantitative approaches to concurrently meet the following three trail based IA&M (impact assessment and monitoring) needs in Mount Robson Provincial Park. 1) Initial research, which improves the knowledge of relationships between human impact and environmental factors. 2) The need for park managers to evaluate the effectiveness of past management policies as well as develop and implement new management techniques. 3) Collect baseline data for a longitudinal study, which will gain new knowledge of changes in natural conditions over time. The proposed methodology assesses new parameters, uses updated indicators and refines previous sampling techniques. The consideration given to site-specific variables including ecosystem characteristics, management utility, agency resources and research goals are described.

1. INTRODUCTION

Ecosystem management has been defined as managing ecosystems while maintaining appropriate human uses (1). The dilemma of these differing, and often competing, priorities is central to backcountry recreation management. Globalization and burgeoning affluence have increased discretionary time and spending concurrently increasing demand for natural resources, for parks and other uses. This has occurred in concert with enhanced awareness of environment and ecological issues, and an increasing desire to sustainably manage natural resources.

Research has shown that increasing and changing outdoor recreation activities pose a threat to park values (2,6). Visitors are known to trample and eradicate vegetation, erode and compact soils, harass and displace wildlife, increase turbity and pathogens in water, and have other primary and secondary impacts (2). These impacts threaten the ability of parks and protected areas to achieve both their preservation and recreation mandates.

Interest in the field of recreation ecology has increased, as this academic discipline is crucial to understanding and managing visitor impacts. Recreation ecology has been defined as a research response to increasing pressure on wilderness areas from recreational visitors (2). The goal is to understand and explore meaningful ways to mitigate impacts, preserve wilderness resources and provide recreation experiences. There has been a significant amount of research on the impacts of recreation on vegetation and soils; however, less research has been completed regarding impacts to water and wildlife.

Backcountry trails are one visitor impact concern for visitors, managers and ecosystem preservation. Trails are a fundamental part of most park and wilderness visits, providing recreation, access, and resource protection by concentrating use. A survey of British Columbians found that 60% use BC park trails for hiking and about 15% for overnight backpacking (3). Visitors tend to notice certain types of degradation, such as litter and graffiti, more so than other ecological impacts but some research suggests that visitors do perceive differences in ecological impact between different types of visitors, such as mountain bikers and hikers (4). This is a potential source of increased conflict amongst visitors. Trails in poor condition also increase fatigue, pose a safety hazard and can reduce visitor satisfaction. Managers rate trail impacts as their "most persuasive management problem" and trail maintenance problems are a leading expenditure in facility maintenance and operation budgets, perhaps as a result of complaints from visitors (6).

The area of backcountry trail impacts is typically small, less than 0.5% in most cases, but the impacts can be locally severe and have appreciable larger scale ecological and social effects (2). Trail impacts interfere with ecological preservation by eroding soils, triggering mass wasting events, and fragmenting wildlife habitat. Despite the ecological impacts associated with trails, trails also provide an important natural resource protection role by concentrating visitor use in specific areas, reducing the dispersion of visitors and impacts. The significance and spatial extent of wildlife and water-based visitor impacts has not been as widely reported in the literature, but there is evidence that trails fragment habitat and influence distribution and abundance of different species (7). Another concern is that backcountry impacts are spread out over large areas in addition to other types of human impacts. For example, in Waterton Lakes National Park, Alberta, there is either a road, trail or both, located in each valley demonstrating the cumulative extent of human influence in the park (8).

While backcountry impacts are an issue in most popular parks and protected areas, a review of the literature suggests that backcountry visitor impacts to vegetation and soils become particularly significant in the following general situations. The first case, from an ecological perspective, is when there are a large number of visitors and (or) an increasing number of visitors with no limits to dispersion and (or) expansion. Another case is when activities are centered on rare or endangered attraction features, which are often the central focus of many wilderness visits. From a recreation management perspective, recreation impacts become significant when site hardening is either inappropriate, given the goal of minimum tool facilities, or too expensive, given the added costs of isolation, the limited construction season, and when the level and types of impacts bother visitors.

1.1 Key Recreation Ecology Findings

The popular media has framed visitor impact and ecological degradation problems as resulting from 'loving the parks to death' or parks being 'over crowded', which reinforces the misconception that overuse is the root cause of poor environmental quality or ecological integrity. Stress and response studies show that impacts occur quickly at first, for the first 500-1000 visitors, and increase slowly with the addition of more visitors (7). The finding that impacts increase, but at a decreasing rate, with greater numbers challenges previous assumptions of 'over use' and also implies that management should be concerned at the initial size of use. This can provide direction for recreation ecology studies and visitor management programs.

Another important recreation ecology finding is that environmental and human factors, rather than the total number of visitors, are the primary influencers of trail condition. This is manifested in a hiking trail that traverses varying topography and has varying trail conditions, but has similar levels of use along its length. One study suggests that the primary influencing factors include the type of use, amount and intensity of use, visitor behavior, timing of visits, site durability and environmental characteristics (7). Leung and Marion reviewed over fifty recreation ecology studies and found that climate and geology, which effect topography, soil and vegetation, combined with user type, intensity and behavior, were the main underlying factors that influence trail conditions (9). While there is general agreement about the importance of influencing environmental and human factors, recent research shows more conflicting results as to the relative effects of these individual influencing factors (10). Understanding the relative effects of the influencing factors is an important recreation ecology question, which can be better understood through the application of more regional and long-term case studies.

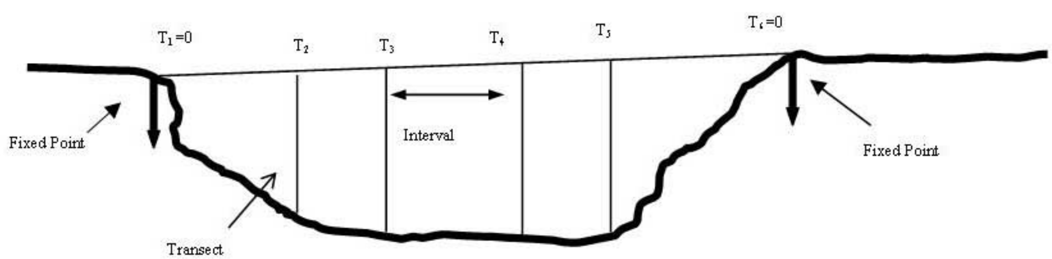
2. TRAIL BASED IMPACT ASSESSMENT AND MONITORING

Increasing use, enhanced awareness of ecological concerns, greater public scrutiny of park management decisions, demands for more participatory land management, and rising popularity of different types of outdoor recreation have led to a greater need to monitor and understand trail impacts using increasingly complex and rigorous methods (4). These methods include sampling-based rapid surveys, census-based rapid surveys and permanent point sampling surveys (11,12, 4). These survey methods collect data on multiple indicators to describe existing trail conditions, identify deteriorating trail conditions, provide information to mitigate unsustainable situations and increase the knowledge about trail degradation. Assessments can be based on sample, census and/or an integration of sampling and census measurements, as is proposed here. Each requires a trade-off to achieve their varying goals effectively and efficiently, but all use detailed quantitative and rigorous empirical techniques to increase knowledge and support decision-making.

2.1 Rapid Surveys

Sampling-based rapid surveys involve systematically locating non-permanent sampling points along the trail. This type of survey collects data on multiple parameters, such as width, incision, and other detracting features (13). Measurements concerning trail width and trail incision have been refined significantly over time (14, 12, 15). Sampling-based rapid surveys are best suited to determining the overall condition of the trail and identifying major changes in condition (13). Sampling points are not permanently established, so it is more difficult to distinguish between changing trail conditions and natural variability along the trail. This system is useful if the purpose is to examine the overall condition of the trail without reference to specific points, features and location- specific attributes.

Figure 1 shows the cross section method used by both rapid surveys and permanent point sampling surveys to understand the change in trail depth, width and the relationship between then two. This method calculates the cross sectional area of the trail, which can be used to compare changes, erosional, depositional, or lateral spread of the trail.



$$\text{Area}^{1\cdots} = (\text{Transect 1} + \text{Transect 2}) \times \text{Interval} \times .5$$
$$\text{Area}^{t} = A^1+A^2+A^3+A^4+A^5$$

Figure 1

2.2 Census Approaches

Census approaches involve surveying the entire trail system, to identify occurrences when conditions exceed specified parameters. A recently developed census method is the problem assessment method, which is an efficient and effective means of determining the presence and extent of trail impacts by collecting information on management problems such as excessively muddy sections, excessive trail width, water on trail, unofficial trails, and soil erosion (12,14). As mentioned, the data set is typically based on presence or absence of conditions; but can also include quantitative measurements of the lineal extent of problems, information that can be useful for planning (12). This method is particularly ideal for planning because the census of the entire trail, at the rate of about 3 km per hour, quickly generates data on how many and what type of repairs are required (16). For example, after completing a problem assessment of trail conditions in Great Smoky National Park, (16) management can plan its maintenance based on the survey findings that there was approximately 300m per kilometer of wet soil.

3. PERMANENT POINT SAMPLING

The permanent point sampling survey method establishes, and marks, survey points at set intervals that can be reassessed to detail any changes that may have occurred (17). As with the rapid survey method, trail parameters typically include width and incision, but can include soil bulk density, aspect, trail alignment, vegetation changes, tread surface characteristics and other trail attributes. Sampling points are permanently marked so changes on variety of indicators can be recorded with the highest level of precision amongst the three methods. Sampling points can be established systematically, with the use of a measuring wheel, or sampling points can be purposely established in known problem areas (11). There is the risk that plots can become obsolete because of new trail construction or relocation. This risk can be addressed, in part, by ensuring that the initial number of plots is large enough, so that there is still adequate coverage if some plots become unassessable in the future.

Table: 1 Comparison of Trail Survey Techniques

Survey Type	Sampling methodology	Key Parameters	Best Use	Weakness
Rapid survey method	Sampling	Width and incision, but can include others (e.g., soil type, vegetation type, slope, aspect, etc.)	Quickly describes trail conditions and identifies major changes	Cannot detect small changes
Problem assessment method	Census	Identifies predefined unacceptable conditions (e.g., erosion, water on trail, multiple treads, etc.)	Primarily a management tool for quickly surveying trails.	Doesn’t generate averages on trail width/incision
Permanent sampling method	Sampling	Width and incision, but can include others (e.g., soil type, vegetation type, slope, aspect, etc.)	Describes trail conditions and precisely identifies subtle changes.	Samples only a small portion of the trail, can be time consuming

A combination of these three methods is proposed for the examination of trail conditions in Mount Robson Provincial Park.

3. PROPOSED INTEGRATED TRAIL SURVEY METHOD

3.1 Study Area

A proposed integrated trail survey method will be implemented on two backcountry trails in Mount Robson Provincial Park, British Columbia. Located about 750 km North East of Vancouver, British Columbia, this 220,000 hectare World Heritage Site provides superb backcountry hiking opportunities in the Canadian Rocky Mountains. The main backcountry attraction is the Berg Lake trail, which provides access to campsites overlooking glacial lakes nestled at the foot of Mount Robson, the tallest peak in the Canadian Rockies. Each year over 15,000 hikers use the 23 km trail for day hiking, backpacking, mountaineering and photography (18). There is also the lesser-used Mount Fitzwilliam trail, which provides more of a wilderness experience to also explore, view and admire the alpine setting and mountain scenery. Previous impact assessments on the Berg Lake trail indicated that ecological degradation, perceived crowding and conflict were the main concerns of both managers and visitors (17). As a result, a visitor management system including a quota/ reservation system and trail monitoring program was implemented in 1996 (19). Constraints in the monitoring program have limited its potential contribution to park management. The Mount Fitzwilliam trail has received little formal impact assessment or research attention.

3.2 Proposed Survey Methods

The proposed integrated survey method consists of using the permanent point sampling approach combined with a modified continuous assessment. The first step in the survey method is the development of a trail manual that outlines the procedures for establishing plots, measuring each variable, recording and analyzing data (a copy is available from the author). This will help ensure consistency across survey crews and facilitate reassessments crucial to long-term research.

Permanent sampling points are established at a sampling interval of between 100m and 500m using a systematic sampling approach, where the distance to the first point is obtained from a random number table (14). In this case, a sampling interval of 500m will be used. This is appropriate given the large size of the trail system. A measuring wheel (circumference 120cm) is used to locate the plots, which can then also be geo-referenced using a Global Positioning System (GPS).

The modified continuous assessment is conducted between survey plots enumerating the occurrences of multiple treads and the type and number of management features. If after surveying the entire trail system no plots are located in problem areas, plots can be purposely established in these areas, using the help of park staff, but the data collected must be kept separate from the random information so as not to bias the analysis.

The Statistic Package for the Social Sciences (SPSS), combined with the spatial analytical powers of a GIS (PC ARC/Info) will be used in data analysis. Once the data is entered, SPSS can quickly create summary tables and (or) test statistical hypotheses. For example, the program can outline the average trail width or incision on different segments of trail different. This can help management and stakeholders visualize the spatial distribution of impacts. Cross-section information can be presented graphically from each plot, then compared to future reassessments to determine if trail cross section is increasing, remaining the same or improving. This method provides a rigorous quantitative understating of soil loss or deposition. Indices can be used to present this information geographically with the use of a GIS. The trail database can be used to describe current conditions and identify trends as part of a backcountry recreation management plan.

Table 2 Assessment Parameters

Variable	Variable description	Instrument	Measurement Scale	Units/ Value
Trail cross section	Index of soil loss (see figure 1)	Cord (rope) and Ruler	Ratio/Interval	cm^2
Vegetation Type	Bio-geo-climatic Zone	Vegetation inventory maps and GPS	Nominal	One of four zone names.
Vegetation Gradient	Vegetation changes, parallel to the trail.	1mX1m folding Quadrat	Nominal	cover, height, & composition
Trail Gradient	Average slope of the trail	Clinometer	Ratio/interval	Slope (%)
Landscape slope	Steepest slope of the landscape.	Clinometer	Ratio/interval	Slope (%)
Aspect	Slope direction of landscape	Magnetic Compass	Nominal	North, South, East or West
Trail Alignment	Index of difference between trail and aspect directions.	Magnetic Compass	Ratio/interval	$0\text{-}90^\circ$
Trail Position	Valley Bottom, Ridge Top, or Mid-slope.	Not applicable	Nominal	N.A.
Elevation	Height above sea level	Topographic Map	Ratio/interval	metres
Exposed Rocks and Roots*	A count of the number of exposed rock or roots over a 5m segment of trail.	Not applicable	Ratio/interval	Area count
Substrate Character-istics	The percent contribution of different substrates to the total trail surface.	Not Applicable	Ratio/ interval	Percent by category
Soil Moisture*	Moisture content of the soil.	Pocket soil moisture meter	Ratio/ interval	Water content by weight (%)
Penetration resistance*	Measures the relative compaction of the soil.	Soil Penetrometer	Ratio/ interval	g/cm^3
Use types	An estimate of the amount of use.	From park statistics	Ratio/ interval	Count
Amount of traffic	Total number of visitors per year.	Estimate from park statistics	Ratio/ interval	Count

*** These will be compared to a control site parallel to each sample point.**

Table 2 Continued ***Continuous Assessments***				
Variable	***Variable description***	***Instrument***	**Measurement Scale**	**Units/Values**
Secondary trails or multiple treads.	Unofficial trails (i.e., Cut switchback.)	Not applicable	Ratio/interval	Count
Site hardening point features.	An identification of a management feature and a qualitative assessment of its effectiveness.	Camera & GPS	Nominal	Count
Continuous assessments will only assess the following two parameters				

Recreation ecology research can be advanced through analyzing the collected data to test hypotheses on the effects of the influencing factors on trail conditions. This can be achieved through relational analysis of environmental characteristics, such as slope or vegetation type etc., and degradation variables such as trail cross section. Some potential hypotheses could include that: Trails are wider in open meadows than in forested vegetation types, trails are more incised on steep slopes, there are more exposed roots in higher slope positions, etc.

4. CONCLUSION

Backcountry recreation management is facing challenges arising from addressing the demands of increasing use on a finite land base in a context of management transparency and public scrutiny. Active backcountry facility monitoring programs are crucial to understanding landscape and facility conditions and identifying trends in their conditions. The proposed monitoring program that is a partnership between park agencies and universities, is being designed to collect quantitative, objective data that concurrently meets management and research needs. The proposed integrated trail survey approach, combines a modified continuous assessment of the trail system with systematically established permanent sampling points aims to balance trail coverage with survey efficiency. A trail database in concert with a GIS will be used to provide useable information designed to support decision-making and advance recreation ecology research, further integrating the science of recreation ecology into Mount Robson Provincial Park's backcountry recreation management.

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